EE 2245 Microelectronics Laboratory

Lab 6: Measurement: Parameter extraction of MOSFET SPICE model

實驗室：_____組別 _____Names and ID Numbers: _____

Material, instrument and software

- CD4007UB MOSFET array × 1; resistors and capacitors
- Power supply, function generator, oscilloscope, and digital multi-meter.
- HSPICE and Awaves

Procedure

The CD4007UB MOSFET array is chosen for our measurements. This array consists of three N-MOSFETs and three P-MOSFETs. The definition of each pin is depicted in Fig. 1. Note that the body terminal in N-MOSFETs should always be connected to the most negative voltage, while that in P-MOSFETs should be connected to the most positive voltage. Also, the CD4007 is a delicate device. Therefore, **make sure you turn off the power supply before changing any circuit connections.** The measured data will be used to extract the SPICE model parameters. The established model will be simulated and verify with the measured results.

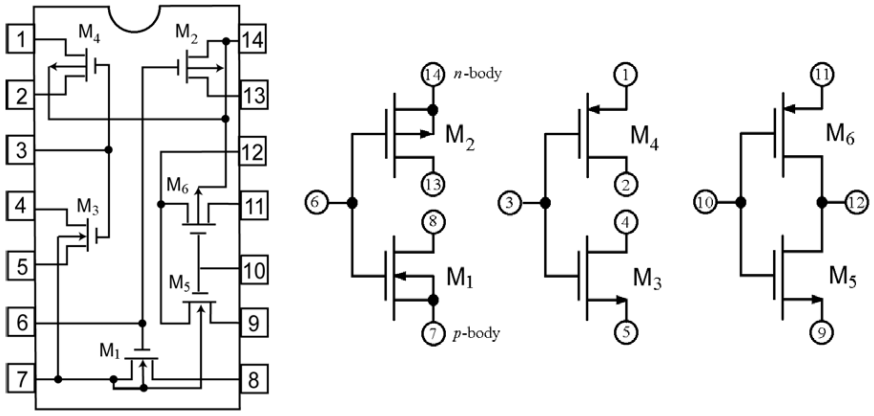

Fig. 1 The CD4007 MOSFET array

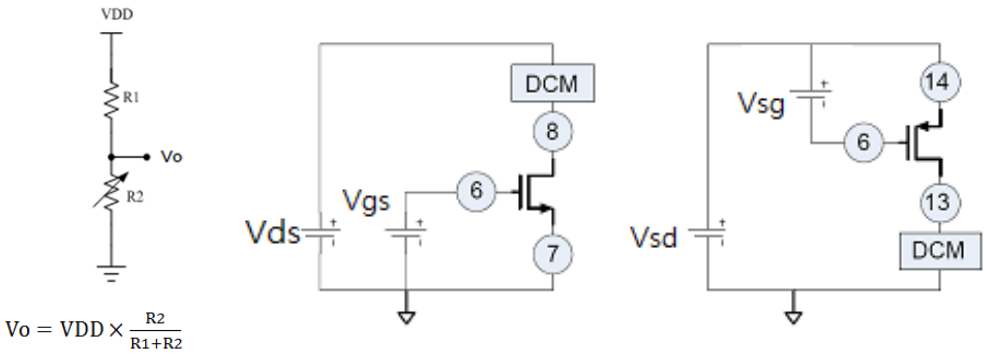

Fig. 2 Test configurations for N-MOSFET (center) and P-MOSFET (right), respectively

A. Measurement of I-V characteristics

1. Measure the I_{DS}-V_{DS} curves of a N-MOSFET (Fig. 2, center) under different V_{GS} (V_{DS}: 0 V to 5 V, 0.5 V/step; V_{GS}: 2 to 5 V, 1 V/step). (你可由 power supply 所提供的固定 5V 經由電阻分壓(Fig. 2, left)產生 V_{GS} 所需的偏壓)

Table 1: N-MOSFET (I_{DS}-V_{DS}); unit: mA

V_{GS}/V_{DS}	**0**	**0.5**	**1**	**1.5**	**2**	**2.5**
2						
3						
4						
5						

V_{GS}/V_{DS}	**3**	**3.5**	**4**	**4.5**	**5**
2					
3					
4					
5					

2. Measure the I_{DS}-V_{GS} curves of an N-MOSFET under a fixed V_{DS} of 3.3 V (V_{GS}: 1 V to 3.3 V, 0.1 V/step).

Table 2: N-MOSFET (I_{DS}-V_{DS}; V_{DS}= 3.3 V); unit: mA

V_{DS}/V_{GS}	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	**1.8**	**1.9**	**2**	**2.1**
3.3												

V_{DS}/V_{GS}	**2.2**	**2.3**	**2.4**	**2.5**	**2.6**	**2.7**	**2.8**	**2.9**	**3.0**	**3.1**	**3.2**	**3.3**
3.3												

3. Repeat steps (1) and (2) for a P-MOSFET (Fig. 2, right). Note: PMOS 的實驗我建議與鄰座同學一起合作，用兩台電源供應器來產生 V_{SG} 及 V_{SD}.

Table 3: P-MOSFET (I_{SD}-V_{SD}); unit: mA

V_{SG}/V_{SD}	**0**	**0.5**	**1**	**1.5**	**2**	**2.5**
2						
3						
4						
5						

V_{SG}/V_{SD}	**3**	**3.5**	**4**	**4.5**	**5**
2					
3					

4					
5					

Table 4: P-MOSFET (I_{SD}-V_{SD}; V_{SD}= 3.3 V); unit: mA

V_{SD}/V_{SG}	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	**1.8**	**1.9**	**2**	**2.1**
3.3												

V_{SD}/V_{SG}	**2.2**	**2.3**	**2.4**	**2.5**	**2.6**	**2.7**	**2.8**	**2.9**	**3.0**	**3.1**	**3.2**	**3.3**
3.3												

B. Parameter extraction

請將模擬程式（後面有附範例）與要求的模擬結果列印出來，與這份報告一起繳交。

1. Based on the measured results, extract the DC parameters V_t (threshold voltage; note: the V_t of PMOS is negative), k_p (transconductance parameter，即μC_{ox}), and Lambda (channel-length modulation) in SPICE level one MOSFET model <u>for both NMOS and PMOS</u>. Assuming the following parameters are known: W= 30 μm, L= 10 μm, and t_{ox}= 100 nm (for PMOS and NMOS).
   Please simulate, based on your own model, in HSPICE for the measurement conditions of Table 1 to 4, respectively, and view the results by using the graphical software (Awaves). Please print out these four figures. **<u>Then you should mark the measured data from Table 1 to 4 on these figures for comparison.</u>** If your procedure is correct, they shall be very close. Within a reasonable range, you can adjust your parameters to fit the measured data better. Also, R_S and R_D (source and drain parasitic resistances) can be added in your model to fit the I_D-V_{DS} curves especially for the triode region.

2. Vary the parameters of the N-MOSFET model one at a time to simulate the I_D-V_{DS} (let V_{GS} = 2V) curves. Please attach the figures and comment accordingly in your report about the changes in I_D-V_{DS} curves.
   (1) V_{to}: from 0.8 to 1.6 V (0.2 V/step)
   (2) k_p: from 50 μ to 250 μ (50 μ/step)
   (3) Lambda: from 0.02 to 0.06 (0.01/step)

lab6.sp - 記事本

檔案(F) 編輯(E) 格式(O) 檢視(V) 說明(H)

```
lab6 n_mos                                  $此為NMOS範例程式

.param  Vtn=1.28                            $電晶體參數
+       kn=156.8u
+       lam=0.0098
+       toxn=100n
+       cbd0=2p
+       cgso=0.1p

.model N_MOS nmos level=1 vto=vtn kp=kn     $將參數讀進自訂模型中建立model
+ lambda=lam tox=toxn cgso=cgso
+ cgdo=cgso cbd=cbd0 cbs=cbd0

****************************************    $Table1 範例    ********************************************

M1 d1 g1 gnd! gnd! N_MOS W=30u L=10u        $呼叫電晶體M1，並輸入長寬
Vds1 d1 gnd! 3.3                            $設定電壓工作點
Vgs1 g1 gnd! 3.3

.DC Vds1 0 5 0.1 sweep Vgs1 2 5 1           $Table1 直流分析指令，針對Vds1與Vgs1進行直流掃描。

.probe dc I(M1)                             $選擇I(M1)輸出為圖形模式

****************************************    $Table2 範例    ********************************************

M2 d2 g2 gnd! gnd! N_MOS W=30u L=10u        $呼叫電晶體M2，並輸入長寬
Vds2 d2 gnd! 3.3                            $設定電壓工作點
Vgs2 g2 gnd! 3.3

.DC Vgs2 0 3.3 0.1                          $Table2 直流分析指令，針對Vgs2進行直流掃描。

.probe dc I(M2)                             $選擇I(M2)輸出為圖形模式

****************************************    $Vary the parameters 範例       ******************************

M3 d3 g3 gnd! gnd! N_MOS W=30u L=10u        $呼叫電晶體M3，並輸入長寬
Vds3 d3 gnd! 3.3                            $設定電壓工作點
Vgs3 g3 gnd! 2

.DC Vds3 0 5 0.5 sweep Vtn 0.8 1.6 0.2      $針對不同參數進行直流掃描分析，
*.DC Vds3 0 5 0.5 sweep kn 50u 250u 50u     $必須消除註解符號("*")分開跑圖形。
*.DC Vds3 0 5 0.5 sweep lam 0.02 0.06 0.01

.probe dc I(M3)                             $選擇I(M3)輸出為圖形模式

.option post probe                          $設定顯示輸出
.end                                        $結束模擬所需指令
****************************************    $範例結束       ************************************************
```